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TELEVISION IMAGES

AN ANALYSIS OF THEIR ESSENTIAL QUALITIES

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(Paper read on Tuesday, April 13th, 1937.)

ABSTRACT.

The subject is introduced by a brief reference to the general principles of television, and the work which has already been done in the photographic and cinematographic field to establish the requirements of a "good picture."

The main treatment deals with the practical limitations to the realisation of the ideal picture imposed by the characteristics of the television system. Picture contrast, range, brightness, definition, size, presentation, colour or tint, and flicker are dealt with. New and accurate methods of measurement of these characteristics are described, and results given.

Cathode ray tube receivers are generally dealt with, but the results are considered to be applicable to other methods of Television reception.

Finally reference is made to possible future developments in television picture reproduction.

(1) Introduction.

This paper is mainly concerned with the factors affecting the quality of the pictures produced in a television receiver, and deals with these problems chiefly from the photometric standpoint. For the sake of completeness, however, and in order to avoid possible misunderstanding, a brief reference will first be made to the general principles and the various stages of the process of transmitting and receiving a television picture.

Fig. 1 shows diagrammatically the various stages, from the subject to be televised, to the final reproduction of the television picture. This diagram is self-explanatory, and serves to emphasise the number of stages involved, from which it will be obvious that the quality of the picture received will be controlled by many factors. In this type of transmitter, the cinematograph type of projector forms an image of the film in the plane of the scanning disc, which is provided with a suitable number of small holes on one diameter, shown diagrammatically in Fig. 2. The downward scan in this case is provided by the steady motion of the film through the gate. The modulated light then passes to the photocell, so producing a modulated photoelectric current which, in turn, is fed to the picture frequency amplifier (Fig. 1). The disc also contains a number of slits, which give a flash of light into the synchronising photocell after each line of the picture has been scanned. The amplified picture and synchronising signals then pass to the transmitter. At the receiving end the signal, after suitable amplification, modulates the light valve, and, in consequence, the brightness of the "spot" on the receiver screen. In the case of the cathode ray tube this spot is made to scan the screen by applying to the deflector plates of the cathode ray tube a voltage of saw tooth wave form, of the same frequency, and in step with the line scanning at the transmitter. This voltage, which is supplied from a suitable time base circuit, ensures that the "spot" moves across the television screen in a succession of lines, in the same manner, and in synchronism with the scanning of the picture at the transmitter. In this way the picture is resynthesised on the television screen.

Another method of scanning the film or scene to be transmitted is by means of an electron camera device. In one such arrangement an image of the film frame or scene is formed on a photocell mosaic, each small globule acting as one plate of a tiny condenser. The small charges stored on the mosaic modulate an electron beam, which is caused to scan this screen, and these impulses, in turn, are fed to the picture frequency amplifier, as before. In the following sections, the main factors influencing the picture quality are dealt with in conjunction with the ideal requirements.

It will be appreciated by reference to Fig. 1 that over a considerable range, and at a number of points in the chain, it may be possible to control the quality of the received picture. Assuming this control is available, we must consider the limitations of the system in order that the optimum effect can be produced.

Before dealing with the problem as it arises in television, it is first necessary to realise the requirements in the production of a black and white picture of any form. The quality of such a picture is controlled by its contrast, brightness, definition, size, presentation, and tint. In the case of a moving picture, there is also flicker and allied effects.

It is quite obvious that even if an exact copy is the ideal to be aimed at, it is not attainable in practice, if only because of the absence of colour, and the third dimension. The aim therefore, should be to reproduce a picture which has the maximum aesthetic value. Having in mind the excellence of some of the paintings and photographs which have been produced, it is interesting to observe the manner in which these depart from the original. The nature of these departures is, of course, usually reflected in the prevailing fashion or style.

The problem from the photographic aspect has been very thoroughly explored, both with regard to still and motion pictures, and as many of the problems are common to any form of black and

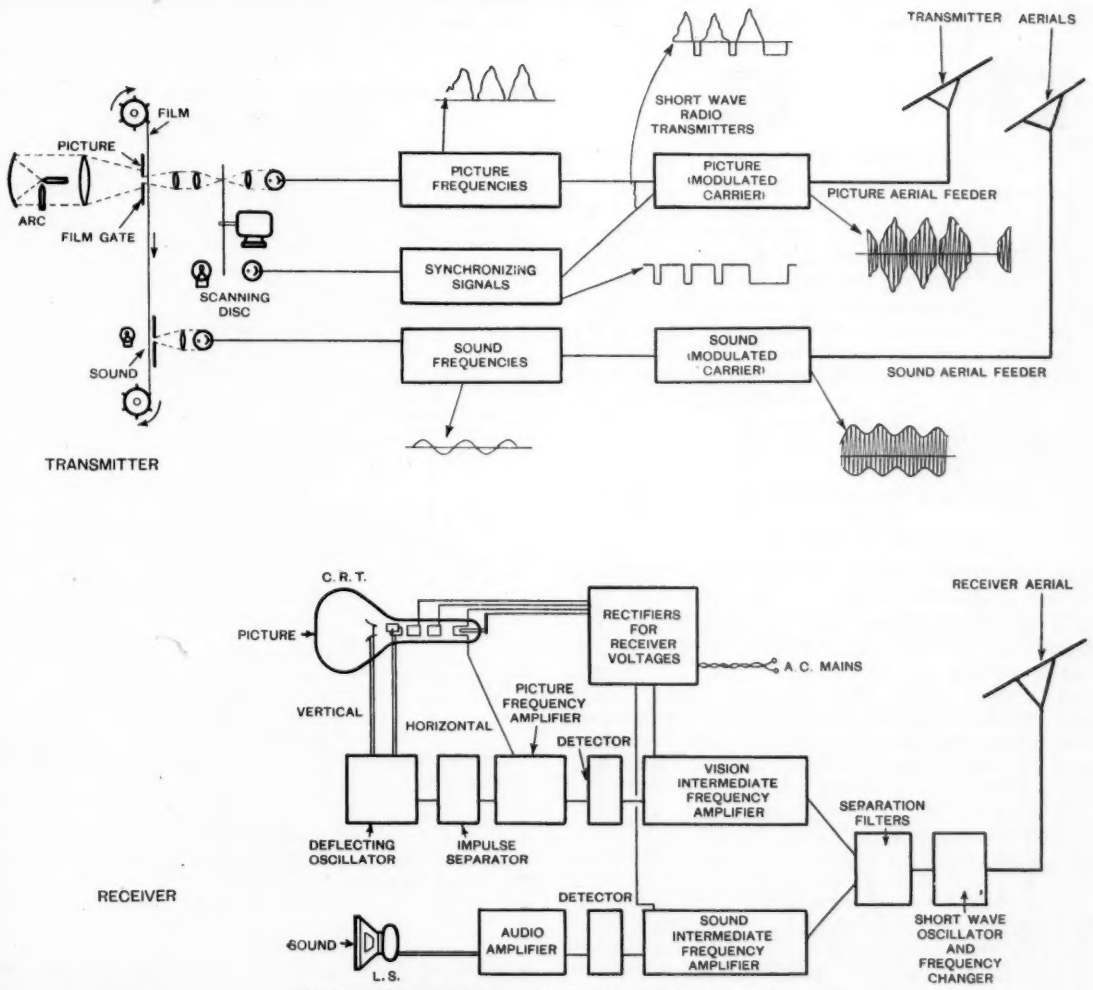


Fig. 1. Schematic Diagram of Complete Television System.

white reproduction, reference will first be made to these.

(2) Photographic Requirements for a Good Picture.

Of the picture properties detailed above, brightness, contrast, range, and presentation are probably the most important characteristics. With the enormous variety of lenses now available, definition is, of course, entirely under the control of the photographer, and is subject to his artistic requirements. Similarly, with the choice of colour or tint, the same considerations apply. With regard to size, pictures are generally of the order of ten by eight inches for exhibition work.

Dealing now with the main characteristics,

(i) Contrast, Range and Brightness.

It has already been shown to this society (1) that the faithful reproduction of tone can be obtained over a useful range with modern photographic apparatus. Further, that controlled departures from the original can be obtained at will. A current publication (2) also deals with the application of these methods to the problem of photographic tone reproduction.

If the relation between the density, or reflection density, is plotted against the logarithm of the brightness of the subject multiplied by the exposure time, then the well-known curve of Fig. 3 is obtained. The slope of the straight portion of the characteristic is known as the contrast, expressed by the symbol γ and the maximum range obtainable on the linear portion is expressed, either as a density or reflection density difference or a ratio of the extreme transmission or reflection values. With unity γ the brightness ratios are the same as in the original subject over the range of the linear portion of the

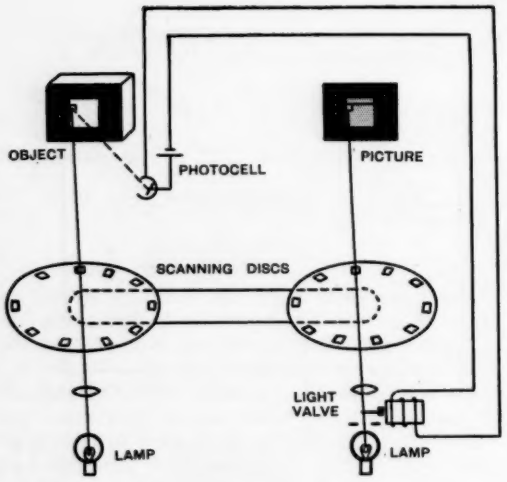
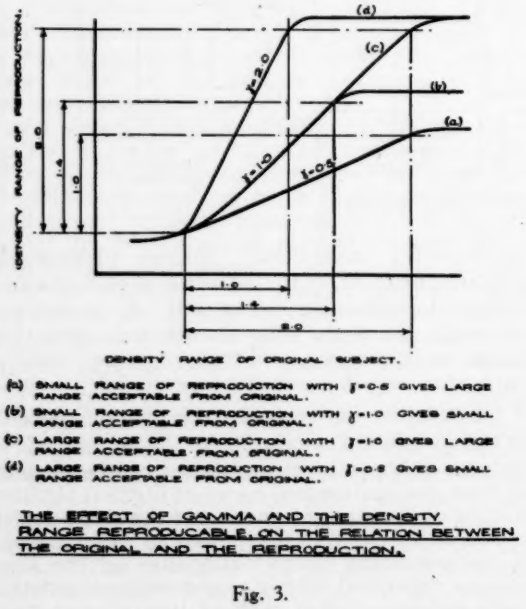


Fig. 2. Diagrammatic Arrangement showing the Principle of Scanning.

curve, and the reproduction is a faithful representation of the brightness ratios of the original.

It will be appreciated that the length of the straight portion of the characteristic in Fig. 3, i.e., the range which is reproducible at a constant contrast varies with the process used. For example, measurements of newspaper reproductions show that the average reflection density range produced by the half-tone block is of the order 0.85


(d)
(c)
(b)
(a)
γ=2·0
γ=1·0
γ=0·5
DENSITY RANGE OF REPRODUCTION.
DENSITY RANGE OF ORIGINAL SUBJECT.
(a) SMALL RANGE OF REPRODUCTION WITH γ=0·5 GIVES LARGE RANGE ACCEPTABLE FROM ORIGINAL.
(b) SMALL RANGE OF REPRODUCTION WITH γ=1·0 GIVES SMALL RANGE ACCEPTABLE FROM ORIGINAL.
(c) LARGE RANGE OF REPRODUCTION WITH γ=1·0 GIVES LARGE RANGE ACCEPTABLE FROM ORIGINAL.
(d) LARGE RANGE OF REPRODUCTION WITH γ=2·0 GIVES SMALL RANGE ACCEPTABLE FROM ORIGINAL.

THE EFFECT OF GAMMA AND THE DENSITY RANGE REPRODUCABLE, ON THE RELATION BETWEEN THE ORIGINAL AND THE REPRODUCTION.

Fig. 3.

(7/1), as shown in Table 1. Even this low range of tones is capable of producing a commercially acceptable result, provided the essential portions of the subject are reproduced.

TABLE I.

Measured contrasts and brightnesses (in e.f.c.) of typical subjects and reproductions.

	White (W)	Black (B)	Surround	General Illum.	Range. $\log \frac{W}{B}$	Range. $\frac{W}{B}$
Outdoor Scene	2000—White house in sunlight	22.0—Black cat in shadow	—	Midday Sun—March	1.95	90
Living Room (see Fig. 8)	1500—Light wallpaper in direct sunlight	0.3—Black fireplace in shadow	—	,, ,,	3.7	5000
,, ,, ,, ,,	25—Light wallpaper in diffused light	,, ,,	—	,, ,,	1.9	80
,, ,, (curtains drawn)	5—Light wallpaper	—	—	,, ,,	—	—
,, ,,	1—Light wallpaper	—	—	At night—artificiallight—240w. indirect	—	—
Person's Head	20—Highlight on forehead	1.0—Dark hair shadow side	25—Light wallpaper	Diffused daylight indoors	1.3	20
Person's Head and Shoulders	,, ,,	0.3—Dark clothes shadow side	,, ,,	,, ,,	1.82	66
Half-tone reproduction (Daily Paper) ..	20	3.0	20	,, ,,	0.85	7
,, ,,	5	0.7	5	Artificiallight (60w.)	0.85	7
Professional Portrait (Matt surface) ..	6.5	0.6	9—White m'nt	Diffused daylight indoors	1.04	11
Photograph—"Still" in Cinema Foyer (glazed print under glass)	10	0.5	3—Grey m'nt	Indirect Artificial	1.3	20
Cinema (screen size from 28′ to 13′ wide).	1 to 15	0.03 to 0.20	0.01 to 0.07—Black	Practically none	1.4 to 1.9	25 to 80
Home cinema (screen 2′ wide, 6w. to 500w. projector lamp) ..	0.5 to 7	0.01 to 0.14	<0.01 Black	,, ,,	1.18 to 1.78	15 to 60
Present commercial cathode-ray tube television receivers (picture about 10″ wide).	1 to 10	0.015 to 0.2	<0.01 Cabinet opening	,, ,,	1.18 to 2.08	15 to 120

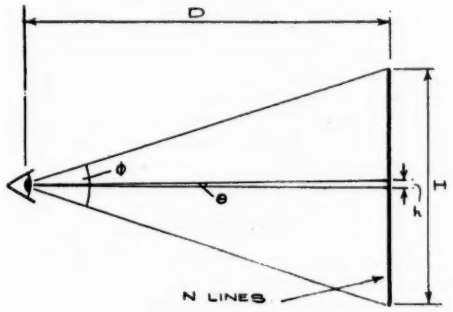
The actual brightnesses of the tones of a photographic print are governed by their reflection factors and their illumination. The range is, therefore, independent of the illumination, and it is found in

practice that for large changes in brightness the appearance of the picture remains sensibly unchanged. (2) (3). Typical values of brightness and range are given in Table I.

(ii) Definition and Size.

Definition and size are interrelated, and will be dealt with in greater detail in Section 4 (ii.) Both depend upon the viewing angle ϕ (Fig. 4) for the effect they produce upon the viewer.

The ultimate definition obtainable in the photographic case is, of course, dependent upon the quality of the lens and the grain size of the emulsion. The



$Nh = H.$
$h = D\theta.$
$H = 2D \tan \phi/2.$

THE RELATION BETWEEN DEFINITION PICTURE SIZE AND VIEWING DISTANCE. (SEE TABLE II.)

Fig. 4.

circle of confusion of a lens has been considered satisfactory at one hundredth of an inch for contact printing, and depth of focus scales have been based on this figure (4). The recent popularity of the miniature camera, with consequent enlargement of the negative, has necessitated the adoption of figures considerably smaller than this (5). From Table II. it will be seen that the resulting definition of a full-plate enlargement would still be of the same order—one hundredth of an inch.

This maximum definition, as computed for the lens, is probably seldom realisable in practice, and it should be noted that intentional de-focussing is often resorted to in practice for artistic effect.

With regard to size, this should be large enough to give a comfortable viewing distance for any picture of artistic merit, but not sc near that the eye has to move unnecessarily over the picture to appreciate it (6). It is a generally accepted principle that the angle ϕ (Fig. 4) should be approximately the same for the viewer as it was for the negative with regard to the lens in the camera, in order that proper perspective shall be maintained. Usually the focal length of a camera is approximately equal to the diagonal of the negative, except for special purposes such as portrait work, where longer focus lenses are used, to avoid unpleasant perspective.

(iii) Presentation and Tint.

White mounts about twice the dimensions of the print have been fashionable for many years now, and recently considerable attention has been paid to the conditions of illumination. Matt-surfaced printing papers are almost universally used, except in special cases such as the treatment of subjects requiring large tone range in their reproduction, and also for press and technical work, where sharpness of focus is important. In both these cases glossy surfaces are of great assistance.

Colours or tints are usually associated with particular characteristics, for example, red, yellow, and sepia, with warmth and soft gradation, whilst blue and mauve give cold and hard effects.

(3) Motion Pictures.

Most of the characteristics referred to in Section (2) are common to motion pictures, with the addition of the problem of eliminating flicker. With this exception, therefore, only the main differences will be dealt with.

(i) Contrast, Range and Brightness.

Here there is a much wider range available, which is common to all transparencies. The average value of the density range of a positive print is 2.0 (100/1) (7). Projected pictures have been measured on the screen in London and suburban theatres, and average values of 1.7 (50/1) have been obtained, with maximum values of the order of 1.9 (80/1) very occasionally (Table I.).

In the case of a projected picture, the limit of range available can be set by the stray light falling on the screen and raising the brightness level of the blacks in the picture. This point will be dealt with in detail under Section (4) (i) when considering the television problem.

The brightness of the projected picture depends to a considerable extent on the size of the screen (8), since the total quantity of light available is limited For the larger cinemas, with screens of twenty feet wide or over, the brightness of the high lights in the picture are of the order of 2 to 4 e.f.c. (equivalent foot-candles).* With the smaller screens of ten to fifteen feet width, brightnesses of as high as 15 e.f.c. were measured. Where the screen possessed directional reflecting properties, the badly placed seats gave brightnesses as low as 1 e.f.c. The brightnesses obtained with the home cinema are of

* One equivalent foot-candle is the brightness of a perfectly diffusing surface of 100 per cent. reflection factor receiving an illumination of 1 foot-candle.
1 e.f.c. = $\frac{1}{\pi}$ candles/sq. ft = 0.318 c./sq. ft.
= 0.000342 c./sq. cm. (Stilb).
= 0.00107 Lamberts.
= 0.00222 c./sq. in.

the same order of magnitude. Typical values for all the above are given for comparison with other data in Table I.

Similar data has already been accumulated elsewhere (9) (10), and an attempt made to establish the optimum conditions of brightness. In the latter paper, it is suggested that a value of 10 e.f.c. for the high lights in the picture is required by the average viewer.

(ii) Definition and Size.

The definition of the cinema picture is probably limited more by the mechanical accuracy with which successive frames can be located in the gate than by the optical system, either in the camera or the projector. In the case of the 8-mm. amateur film, the limit of the grain of the emulsion has probably been reached.

It has already been suggested that the cinema is probably equivalent in definition to a true 400-line television picture (12), and it will be seen from

TABLE II.

Picture size, definition and viewing distance for typical pictures.

(See Fig. 4.)

	H	L	N	D	θ	ϕ	D/H
Photograph:							
Full plate ...	6½″	1/100″ (a)	650	11″	3.1′	33° (b)	1.7
Quarter plate	3¼″	1/250″ (a)	810	5½″	2.5′	33° (b)	1.7
Miniature ...	24mm.	1/30mm. (a)	720	50mm.	2.3′	27° (b)	2.1
Cinema Theatre	23′ to 10′	—	—	100′ to 30′	—	13° to 19°	4.3 to 3.0
Home Cinema...	1′ 6″	—	—	5′	—	17° (b)	3.3
Present Commercial Television receiver	8″	1/40″	320-340 (d)	3½′	2.0′ (c)	11°	5.25

(a) See Refs. (4) and (5).
(b) Approximately equal to angle subtended by negative in camera.
(c) Maximum acceptable (12).
(d) Present B.B.C. transmissions.

Table II. and Fig. 4 that the ratio between the value of ϕ for photographic and cinematographic reproduction would support this view.

With regard to size, it is interesting to note that the best seats in a cinema are furthest from the screen, and the size of the screen is usually adjusted to suit the auditorium and give a value for ϕ of about 15 deg., as shown in the table (6). This angle corresponds with the angle subtended by the negative film frame at the lens of the average camera, so that proper perspective is maintained as in the photographic case.

(iii) Presentation and Tint.

A black surround is almost universally used in this country to-day. Recent work in the U.S.A., however (9) (10) (11), indicates that an illuminated surround is to be preferred, both improving the contrast and reducing fatigue. The use of such a surround field is not new to photometry, of course, where it has been used now for many years for these very purposes. For cinema work, the illumination of the surround must be so arranged that no stray light from it can fall on the picture, or the contrast will be spoilt. The actual values of surround brightness suggested are at the most 0.2 e.f.c., which is 1/50 of the recommended brightness for the high lights given above.

Certain small changes of tint have been observed, due to different types of high intensity carbons, and different tinted film bases being used. Except for special effects, it is believed that the blue/white tint is preferred in general.

(iv) Flicker.

Flicker is relatively non-existent in the cinema, where the use of multiple interruption for each frame has put the frequency of light interruption outside the flicker limit, except, perhaps, for the very brightest case (15 e.f.c. on the high lights of the picture), where flicker was just perceptible on a bright moving object.

(4) Television.

Of all the qualities of pictures so far discussed, the definition is undoubtedly the controlling factor in television reproduction. Even when a basis of transmission is established (number of lines), the best use that can be made of the theoretical definition available is open to a number of practical and commercial solutions. In the following discussion the relation between definition and the other important qualities will be indicated, and a method of measuring the definition from the optical or electron-optical portion of the receiver described.

Control of brightness and contrast are entirely electrical, and therefore probably more flexible and easily controlled than in any other known picture-reproducing system. They are also for the same reason subject to greater random variation.

The main characteristics of television images will now be discussed in detail.

(i) Contrast, Range and Brightness.

From the previous discussion, and Table I., it will be seen that tone ranges of 1.5-1.7 (30-50/1) appear to give very satisfactory results in practice, and values as low as 1.0 (10/1) are tolerable under certain conditions.

The effect of the shape of the brightness characteristic of any system of picture reproduction is shown in Fig. 3. It will be seen that the ratio of the brightnesses in the original to those in the reproduction are controlled by the slope, or γ, of the characteristic, and the range of brightnesses which can be dealt with and reproduced, by the length of the straight portion of the curve. It is very important to realise that if a given tone range of the original is to be reproduced, then at high γ the reproduction has to have a very much increased range. Thus for a density difference of 1.0 (10/1) in the

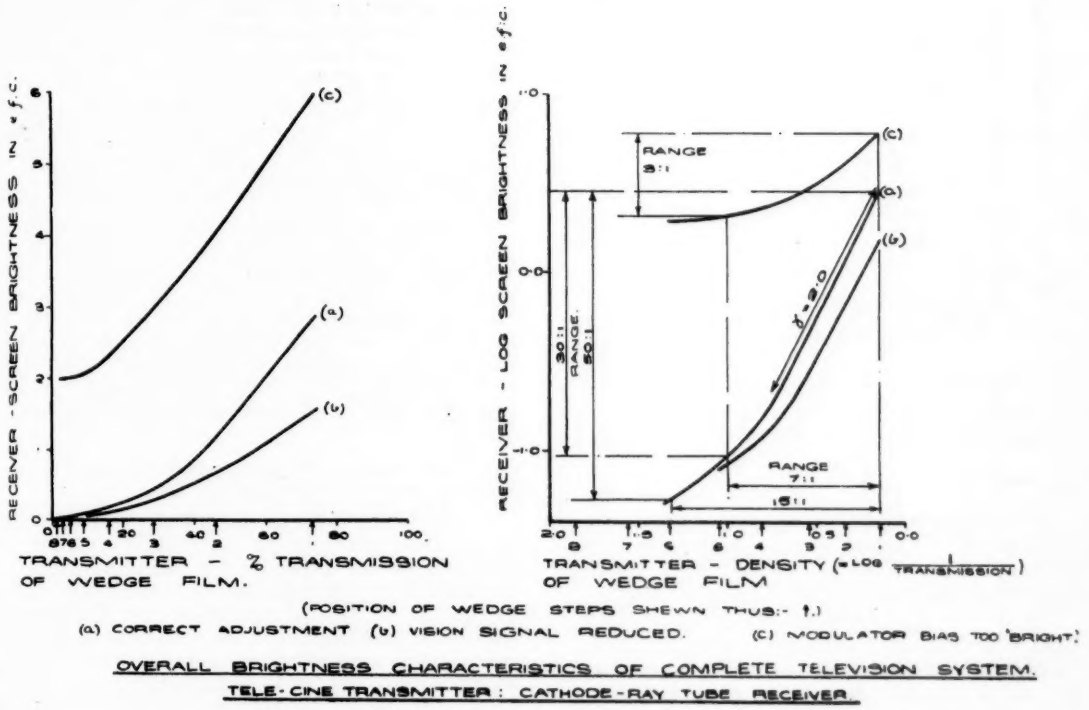

RECEIVER - SCREEN BRIGHTNESS IN f.c.
(c)
(a)
(b)
TRANSMITTER - % TRANSMISSION OF WEDGE FILM.
RECEIVER - LOG SCREEN BRIGHTNESS IN f.c.
RANGE 3:1
30:1 RANGE 50:1
γ = 2.0
RANGE 7:1
15:1
TRANSMITTER - DENSITY (= LOG 1/TRANSMISSION) OF WEDGE FILM
(POSITION OF WEDGE STEPS SHEWN THUS:- ↑)
(a) CORRECT ADJUSTMENT (b) VISION SIGNAL REDUCED. (c) MODULATOR BIAS TOO 'BRIGHT.'
OVERALL BRIGHTNESS CHARACTERISTICS OF COMPLETE TELEVISION SYSTEM.
TELE-CINE TRANSMITTER: CATHODE-RAY TUBE RECEIVER

Fig. 5.

original, a density difference of 2.0 (100/1) is required if the reproduction has $\gamma = 2$.

The determination of such characteristics for a television system has been carried out as follows. An illuminated step wedge was set up in the transmitter, and the brightnesses of the steps measured and compared with the brightnesses reproduced on the receiver screen. The results of such measurements made on a television film transmitter using disc scanning with a cathode-ray tube receiver are shown in Fig 5. In this case a special step wedge film was used (Fig. 6). This was made by the Kodak Laboratories, and consists of eight steps covering the gate of the ordinary sound film projector, and having a density range of 0.14 to 1.86 (50/1) (Fig. 7). The variation of density along some seventy feet of film is less than $\pm$ 0.03.

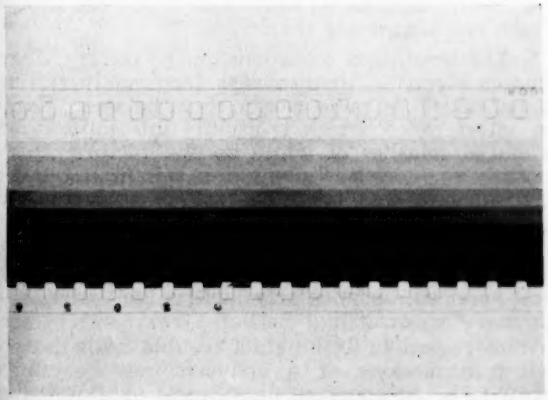


Fig. 6. Graded Density Test Film

Two controls are normally available to the user of a television receiver, for the control of the tone values of the picture. One of these governs the amplitude of the modulating signal applied to the cathode-ray tube or its alternative. It corresponds to the "volume" control of a radio receiver. The other control is for adjusting the steady potential of the modulating electrode, so that the signal from the receiver modulates it over the correct range.

The effect of the two receiver controls on the characteristic of the complete television system measured is shown in Fig 5. The curves are shown plotted on both linear and logarithmic co-ordinates. It will be seen that the effect of the signal control of the receiver is to reduce the overall brightness of the received picture or pattern, without altering the γ, and therefore the tone ratios. The effect of

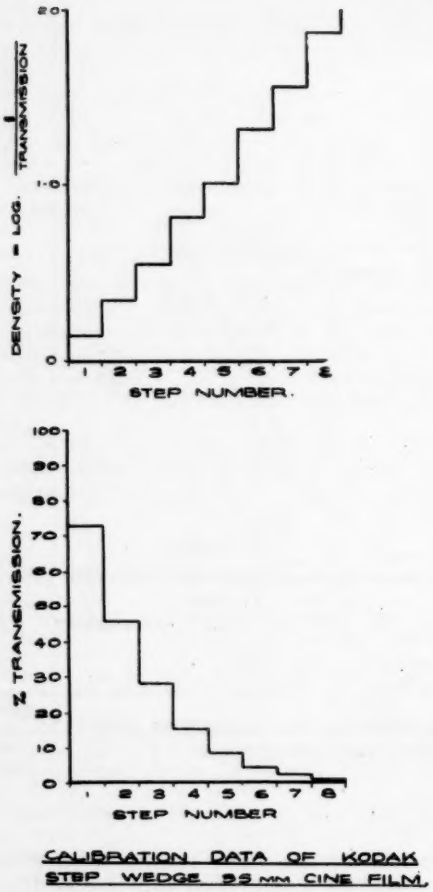


Fig. 7.

the bias adjustment is to alter the level of the tones in the picture, keeping their brightness differences practically constant. Adjustment of this control is comparatively critical, as will be seen, for misadjustment produces either a reduction of the range, as shown in Fig 5, or else loss of detail in the blacks.

It is interesting to note that the characteristics given in Fig. 5 show a high γ for the system, with corresponding reduction of the tone range that can be transmitted. Actually, with this particular transmitter, it has been necessary to use special low γ films to obtain adequate tone rendering in the final picture (13).

It is hoped that such methods of obtaining the overall characteristics of a television system will be followed up by those concerned. In this connection it can be remarked that probably one of the greatest and most noticeable improvements in the B.B.C. transmissions since their inception is the tone rendering of the pictures. As will be seen from Table I., ranges as high as 2.08 (120/1) have been measured on occasions with a good receiver.

In no system of picture reproduction hitherto available has it been possible to control the picture characteristics and observe the effect immediately. In this connection television is so far unique, and it is to be hoped that much will be learnt from it, to the advancement of picture reproduction generally.

The actual value of the brightness of the television picture is very important, in view of the particular conditions under which it has normally to be viewed. In order that adequate tone range shall be maintained in the received picture, a very important factor must be considered, namely, the brightness of the deepest black in the picture. Here, at first sight, television seems to offer an advantage over other picture reproducing systems, as the scanning spot can be completely blacked out by suitable adjustment of the receiver controls. Hence true black and infinite range should be obtainable. Unfortunately, this condition could only be realisable in practice, provided five conditions were perfectly attainable. These are:—

1. The black level at the receiver and transmitter must be correctly adjusted initially.

2. The black level of the signal must be absolutely maintained throughout the whole system for the duration of the transmission. Slow variations could, of course, be compensated for manually, but rapid variations, or local inequalities over the screen, cannot be so treated. It is obvious that a variation in black level amounting to 1 per cent. of the vision signal amplitude, will reduce the maximum range obtainable to 2.0 (100/1) or less, 2 per cent. to 1.47 (50/1) or less, etc.

3. Light must not be reflected from the bright portions of the picture, back on to the black parts. Normally this can occur with any projected picture, by light from the picture being reflected back from the walls of the room. In the particular case of the cathode ray tube, as used for television reception, internal reflections can occur inside the bulb, and special precautions in the nature of non-reflecting coatings on the bulb, have to be used to reduce this to negligible proportions.

4. There must be no other source of light present, which can illuminate the screen.

5. The brightness variations on the picture, due to random electrical disturbances (commonly referred to as "noise" in radio work), must be zero. Except for interference, which is usually intermittent, and produces splashes of white on the picture, this is sensibly so. "Noise" alone does not limit the density range to less than 2.5 (300/1) under normal conditions.

Of the above items, 2 and 4 are undoubtedly the limiting factors at the moment, with 4 probably the most serious, particularly with the advent of summer "viewing."

With regard to 2, the chief trouble with the present transmissions, if a criticism may be offered, seems to be an apparent unevenness of illumination of the subject at the transmitter. It is believed that this is due to some non-uniformity of the photo-cell

mosaic of the transmitting tube, and is more particularly noticeable on the film transmissions, where changes of scene occur too rapidly to be adequately "monitored." This effect has not been noticed to the same extent on mechanical scanners, where the light source and photocell are the same for each picture point.

With regard to 4, television presents a special problem, as, in general, the picture has to be viewed under conditions of quite high general illumination, including daylight. Shielding the screen, for example, with a viewing tunnel will assist matters, but, unfortunately, such devices, if at all efficient, narrow the angle of viewing considerably, and should be considered with caution. Other devices have been proposed (14), and the use of fluorescent materials of low reflection factor will also assist.

Typical values of stray illumination, and the effect on screen brightness, have been determined, and are given in Table III. The example chosen for the

TABLE III.

The effect of stray light on the screen of a television receiver.

(See Fig. 8).

	Brightness of cathode ray tube screen in e.f.c. (Receiver switched off).	Illumination of front of cabinet in foot candles.
At night—room in darkness ...	<0.002	—
" " —room lights on (240w. indirect centre fitting)	0.6	1.8
At night—Standard lamp on in corner (60w. parchment shade)	0.03	0.18
Midday bright sun, March ...	8	20
Midday, bright sun, March, with Tunnel (a) in front of screen	1	2.0 (b)
Midday with curtains drawn ...	1.5	3.5
Midday, with curtains drawn, and with Tunnel (a) in front of screen	0.25	0.5 (b)

(a) Tunnel of black paper 16" × 14" opening and 18" deep, in front of 10"×8" screen. Angle of view limited to ±10° horizontally.

(b) Measured inside tunnel.

measurements was a rather bad case for the daylight readings, as the receiver was placed beside a large window facing south-west, a window on the opposite side of the room admitted light straight on to the screen, and the walls were very light. A plan of the room is given in Fig 8.

From Table III. it will be seen that the range of background brightness, which will normally have to be dealt with by a television receiver, is probably of the order of 0.03 to 1.50 e.f.c. With a very small

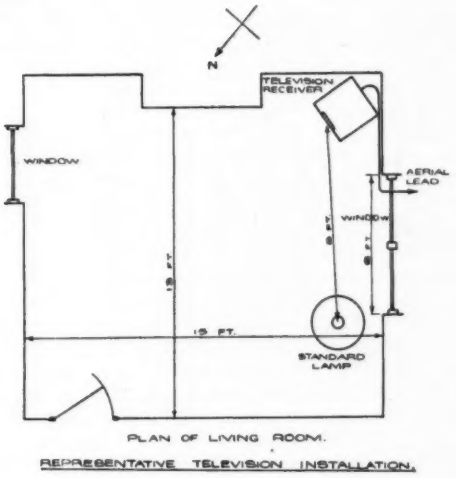


Fig 8.

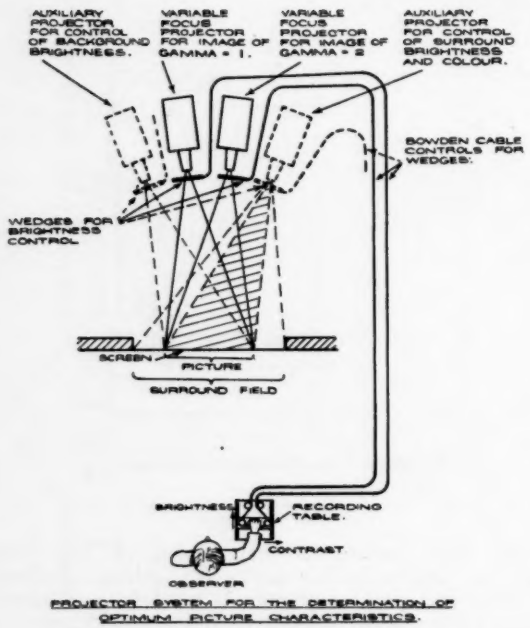
range this means a brightness of the highlights of 15-20 e.f.c. for daylight viewing. Probably 10 e.f.c. will prove sufficient if used with a suitable tunnel, and would then give quite good range—1.6 (40/1) in the example given.

The problem of viewing at night, or in a properly darkened room, may be considered as solved as far as brightness is concerned. Values of 2-3 e.f.c. give a comfortably bright picture for viewing with a fair degree of local lighting in the room, and ranges as high as 2.08 (120/1) have been observed in a darkened room.

It will be noted from the previous discussion that the range of tones normally presented to the eye is of the order of 1.5-1.7 (30-50/1) (Table I. and (1) (2)). There seems to be a tendency at the moment for commercial television receivers to produce pictures with γ greater than unity. This may be because of the popular taste for contrasty (high γ) photographic prints, and does, it is suggested, give a better impression of the picture to the uninitiated. The discriminating viewer will, no doubt, in time, demand more faithful tone rendering.

Undoubtedly, a fixed standard of transmission over the required tone range, is to be aimed at. Artistic manipulation can then be introduced at the proper point—in the studio—and can be entirely under the control of the programme producer, within the known limits of the system. It may ultimately prove desirable that this fixed standard shall be one of low γ from the point of view of power economy at the transmitter. A corresponding high γ in the receiver would compensate for this, the whole system then being roughly analagous to "volume expansion" as at present being introduced into radio receivers.

The most acceptable quality of picture for various conditions of viewing, such as the home, the public demonstration room etc., is at present under investigation. The apparatus used is shown in Fig. 9, and


AUXILIARY PROJECTOR FOR CONTROL OF BACKGROUND BRIGHTNESS.
VARIABLE FOCUS PROJECTOR FOR IMAGE OF GAMMA = 1.
VARIABLE FOCUS PROJECTOR FOR IMAGE OF GAMMA = 2
AUXILIARY PROJECTOR FOR CONTROL OF SURROUND BRIGHTNESS AND COLOUR.
BOWDEN CABLE CONTROLS FOR WEDGES.
WEDGES FOR BRIGHTNESS CONTROL
SCREEN
PICTURE
SURROUND FIELD
BRIGHTNESS
RECORDING TABLE.
CONTRAST
OBSERVER

PROJECTOR SYSTEM FOR THE DETERMINATION OF OPTIMUM PICTURE CHARACTERISTICS.

Fig. 9.

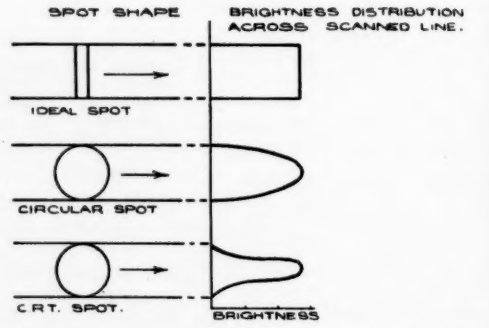
consists of two projectors, each of which can be separately controlled for brightness. These projectors are arranged to project the same image, but with different γ. The two images are exactly superimposed on the screen, and by mixing the light from the two projectors in different proportions, any value of γ (to a very good approximation) can be obtained in the resulting image, between the extremes of the two separate images. The brightness can also be varied independently of the γ. By this means it is hoped to be able to determine the best conditions of reproduction for different types of subject, and for different degrees of sharpness (definition) of the image. The whole arrangement can, of course, be quite easily adjusted for different picture sizes, over a wide range. Auxiliary projectors can also be used as shown, to determine the effect of stray light on the screen, and also to illuminate the surround field with any combination for brightness and colour. The latter will be dealt with in greater detail under Section 4 (iii).

(ii) Definition and Size.

The definition of a television picture is so intimately linked with all the other characteristics, that it probably controls the final picture quality almost entirely.

The basic principles of television, including scanning, aperture distortion, etc., have been adequately summarised elsewhere (15). It is sufficient to say here that the picture is divided up into elements (or picture points), and that these are transmitted in rows (or lines), and re-synthesised by the modulated spot moving on the receiver screen. Persistence of vision gives the effect of continuous illumination of each point of the received picture. It is the number of elements, or lines, into which the picture is divided. which controls the maximum definition obtainable in the final picture. Defects or deficiences in the whole transmitter receiver chain, can materially reduce the definition below this maximum figure.

As already indicated, the size of the element of the picture is referred to in terms of the number of lines into which the picture is divided for transmission. With horizontal scanning, the height of the element is equal to the width of a line, and the element is usually considered as being rectangular. The shape of the ideal scanning spot for use in both transmitter and receiver, would be a line, or at most a very narrow rectangle, whose height is equal to the line width, and breadth the minimum possible (Fig. 10). Owing to the practical difficulties of obtaining other than symmetrical scanning spots (round, square, etc.), and also of increasing the brightness



BRIGHTNESS DISTRIBUTION ACROSS SCANNING LINE FOR VARIOUS TYPES OF SPOT.

Fig. 10.

sufficiently, some loss of definition due to this aperture distortion (16) has had to be incurred.

From Table II., it will be seen that the highest standard of definition at present obtainable with any picture-reproducing system is probably at least 700-800 lines. This, it is felt, can be considered adequate for all present considerations. The present standard of the B.B.C. service is 320-340 lines on the picture, as 15-20 per cent of the 405 lines nominally transmitted, are used for synchronising and other control purposes.

The exact significance of differences in definition has been the subject of much discussion. The limit of acuity of vision has been investigated for television line systems, and values between 0.5 and 1.5 minutes of arc have been obtained under various conditions, with a tolerable maximum value of about 2 minutes (12). A picture of limited definition has

a correct viewing distance, dependent on this angle, apart from that necessary to give true perspective If this correct distance is exceeded, then the eye of the observer is not capable of resolving all the detail in the picture, which is wasteful, and if the distance is reduced below the critical value, then lack of detail becomes apparent. As seen from Fig. 4, therefore, for a given value of θ (2 minutes maximum) the values of N (number of lines), D/H (ratio of viewing distance to picture height, and ϕ (the angle subtended by the picture height at the viewer's eye), are all interrelated. Any of these three quantities serve to define the definition of the picture, provided θ is given, and it is suggested that the last two (D/H and ϕ) are of more practical value than N. It should be noted that all these quantities are independent of the actual picture size.

The values of the above quantities are given for various types of picture reproduction in Table II. As has already been stated, it is an accepted photographic principle that ϕ should be the same as the angle subtended by the negative at the lens, in the camera, in order that proper perspective shall be maintained. This has been used to determine ϕ, and hence θ, for the photographic examples in the Table. It will be seen that it gives values of θ between 2′ and 3′, which is outside the maximum limit stated above. As the definition of a photograph usually leaves no cause for comment, the following are suggested as possible explanations. Firstly, the definition of a photograph may be effectively greater than that given by the circle of confusion of the lens used, due to the fact that the light distribution may not be uniform within the circle. This possibility will become apparent from the discussion on television receiver scanning spots which follows later. Secondly, it may not be necessary to satisfy the absolute limit of acute vision in order to produce a satisfactory impression of sharpness in the image. particularly if there are no definite lines or similar pattern to attract the attention. Thirdly, of course, photographs are usually viewed with a smaller value of ϕ than is demanded by considerations of perspective, but this is thought to be an unlikely explanation.

The difference between the values of ϕ for the cinema, and television pictures should be noted. The indications are, from their ratio, that the cinema definition is probably equivalent to 400-500 lines (on the picture), which agrees with the findings of others (12).

In order to make the maximum use of the definition available with a given number of lines, an exact knowledge of the dimensions, and light distribution, of the scanning spot at the transmitter and receiver must be obtained. For example, to a first approximation the light flux in the scanning spot is proportional to the square of its diameter. This fact is of fundamental importance in television and has proved one of the most serious limitations from the commencement of the art. Thus, doubling the number of lines in a picture will halve the spot diameter, and reduces the light available at the transmitter and the brightness of the received picture, to one quarter of its previous value. With the present B.B.C. transmissions the brightness of the spot has to be some 200,000 times the required picture brightness. This difficulty has now been overcome at the transmitter by the development of photo-electronic devices, such as the electron camera (iconoscope and emitron) and the electron multiplier, and in the receiver by the large screen, high vacuum, cathode ray tube.

Realising, therefore, that the effect of a television picture is produced both by high brightness, to give good range, and also by obtaining the maximum definition, the importance of knowing the exact brightness distribution of the spot becomes apparent. Apparatus has therefore been developed for this purpose and will now be described.

The apparatus shown in Fig. 11 was designed particularly for measurements on cathode ray tubes, and it was therefore considered essential that the measurements should be taken under conditions of screen excitation strictly comparable with those of television reception. For example, it would seem impossible to determine with any accuracy the brightness distribution from the stationary spot, both because of burning or saturation effects of the fluorescent material under the intense bombardment, and also because of the possibility of changes in beam current distribution due to local charges being produced on the screen, etc. A modified form of deflecting circuit has therefore been developed. This consists essentially of a normal frequency time base (A) with the oscillating valves so biased that they are not in the self-oscillating condition. This circuit is tripped by a suitable impulse every 1/25 of a second, and it then traces one line (B) across the screen at the usual line velocity, i.e., in 1/10125 second for the present 405-line pictures. The spot is therefore made to energise the fluorescent material with the one line, in the same way as it is energised during the scanning of the picture.

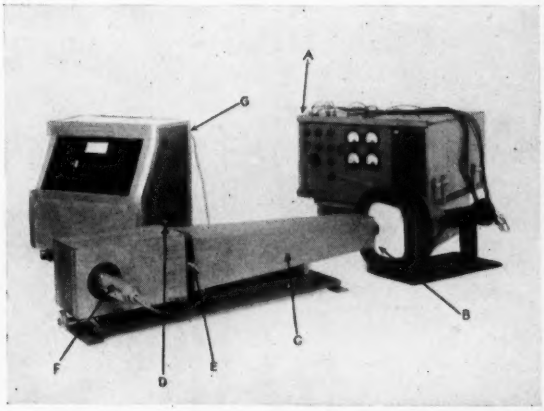
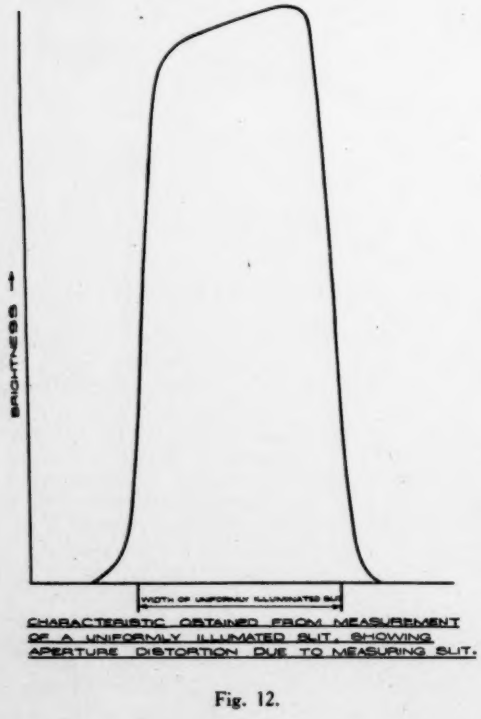


Fig. 11. Apparatus for Measurement of Line Brightness Distribution.

As the spot only moves effectively in two directions at right angles to each other when scanning

the television picture, it is obviously sufficient to know the light distribution across the spot in these two directions, and this simplification has been introduced into the method of measurment. In the photograph (Fig 11) one form of the apparatus used for the brightness distribution measurements is shown on the left. It will be seen that it consists of an enlarging camera (C), with a wide aperture lens, which projects an image of a portion of the line about 1 cm. long on to a slit. The magnification of the camera is ten times, and the dimensions of the slit are 10 cm. × 1 mm. The slit has two adjustments; one (D) for tilting it to bring it accurately into line with the image, and the other (E) for traversing it across the image. The light passing through the slit is collected by a condenser lens, and projected into the photocell of a universal photoelectric photometer (17). This is a transportable light measuring instrument of high stability, and capable of a repetition accuracy of $\pm$ 0.5 per cent. in the comparative measurement of light sources of the same colour, down to 5.10^{-5} lumens, or, if used with a sensitive external galvanometer, to 5.10^{-7} lumens. In this particular application, the photometer unit, consisting of the p.e. cell, an electrometer triode valve, and grid leak, all enclosed in an evacuated glass bulb, was housed in a screened container (F) and connected by a screened cable to the other amplifier components housed in the control cabinet (G).

The procedure with the apparatus is as follows: The cathode ray tube is set up with the special deflecting circuit, and the spot velocity checked by means of an oscillator of known frequency connected to the other pair of deflecting plates of the tube. The camera is then focussed on the line and the focussing screen replaced by the measuring slit. This is traversed to the edge of the image and then adjusted for alignment by tilting it for minimum light on the photocell. The reading of the photometer is then plotted against the position of the slit, as read by the traversing micrometer, and by this means the brightness across the line can be determined. As would be expected in such an arrangement aperture distortion occurs, due to the finite size of the slit. This effect is shown in Fig. 12, which gives the characteristic obtained with the apparatus, from



CHARACTERISTIC OBTAINED FROM MEASUREMENT OF A UNIFORMLY ILLUMINATED SLIT, SHOWING APERTURE DISTORTION DUE TO MEASURING SLIT.

Fig. 12.

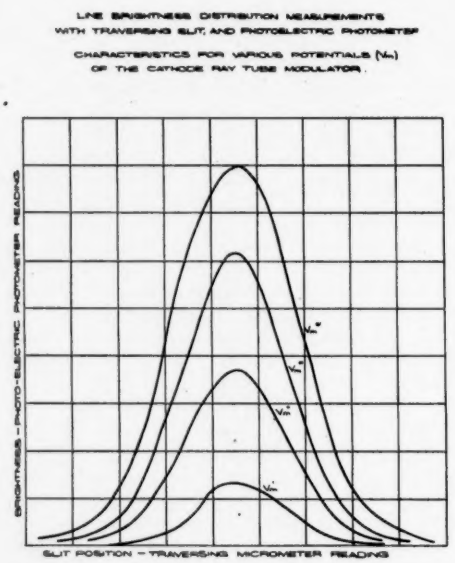

LINE BRIGHTNESS DISTRIBUTION MEASUREMENTS WITH TRAVERSING SLIT, AND PHOTOELECTRIC PHOTOMETER
CHARACTERISTICS FOR VARIOUS POTENTIALS (Vm) OF THE CATHODE RAY TUBE MODULATOR.
BRIGHTNESS - PHOTO-ELECTRIC PHOTOMETER READING
SLIT POSITION - TRAVERSING MICROMETER READING

Fig 13.

an evenly illuminated slit. This data shows the correction for aperture distortion which must be made to the observed values. The size of slit chosen allowed some latitude in favour of the amount of light passed on to the photocell. The performance of the photoelectric photometer in this work has more than exceeded expectations, and it is proposed to take advantage of this to reduce the width of the slit. Typical characteristics obtained with the apparatus are given in Fig. 13.

An alternative method of measurement has been developed based on photographic technique. The same camera is used as in the photoelectric method just described, the travelling slit being replaced by a plate carrier and the condenser and photocell removed. It would, of course, be possible to make a direct enlargement of the line on the cathode ray tube screen photographically, and then by controlled development and densitometry (1) to determine the brightness distribution across the line. A simpler

method, however, is to photograph the line through a continuously graded wedge, developing the resulting negative to a high γ and printing on very contrasty paper. By this means accurate control of development and all densitometric measurements are obviated, the brightness characteristic of the line being reproduced as a curve on the final print. It is merely necessary to transfer the density scale of the wedge to the print to obtain the relative brightness readings. Typical results are shown in Fig. 14. By means of the travelling plate carrier it is possible to

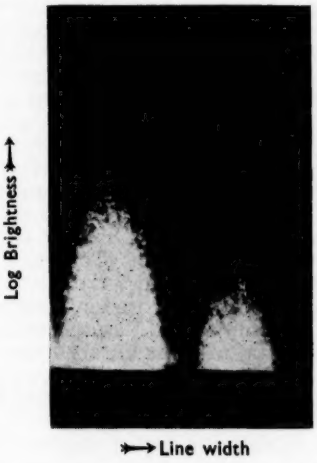


Fig. 14. Line Brightness Distribution Measurements by Photographic Method.

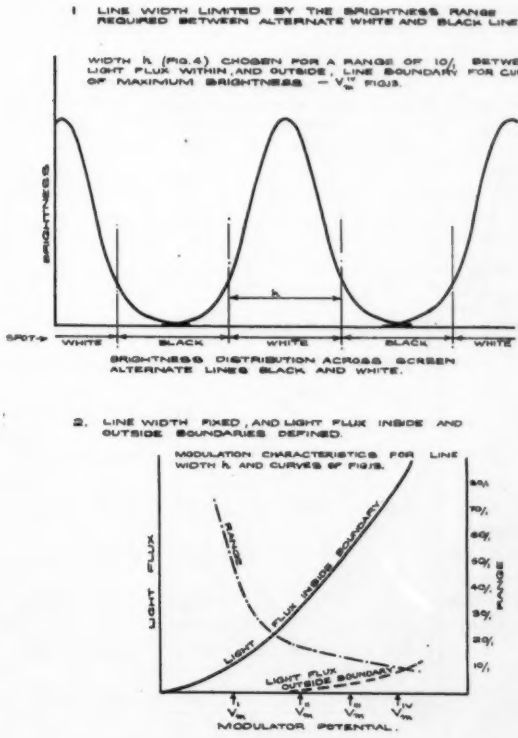
obtain a series of curves, for example, a modulation characteristic, on one plate. Absolute values can be obtained by exposing one section of the plate through the wedge to an evenly illuminated surface of suitable known brightness. This will give a calibration point. Alternatively, two crossed wedges of suitable dimensions and characteristic may be photographed under a known illumination, and a complete calibration curve obtained.

The determination of the cross-section of the spot in the direction at right angles to normal scanning has been obtained by connecting the special deflecting circuit to the other pair of deflecting plates of the cathode ray tube, thus producing the line at right angles to its original direction. This is not an accurate reproduction of the way in which the fluorescent screen is energised, for this direction of measurement, and the possibility of the results being misleading when dealing with definition along the line, must be borne in mind. A more correct method would be to scan the screen of the tube and produce a stationary pattern with a vertical black/white edge, and to examine this edge with either of the methods described. This is under consideration. The present compromise does, however, allow an accurate measure of the degree of astigmatism of the spot to be obtained. This in itself is of value, as it enables observed effects to be related to measured characteristics. As already mentioned, there is some preference for a spot with a height equal to the line width and a breadth considerably less than this.

A possible source of failure when the apparatus was first considered was thought to be the difficulty of keeping the line on the cathode-ray tube screen sufficiently stationary whilst the measurements were were being made. Stray electrostatic charges might have upset the results, for example. This fear proved, fortunately, to be without foundation, as indicated by the high order of repetition accuracy obtained. A possible source of error in the measurements may be the difference in colour sensitivity of both the photocell and the photographic plate from that of the eye. Special filters can be used to correct this, and the point is being checked.

The results obtained show that the brightness distribution across the line possesses a tail, or fringe, on either side, which makes an exact assessment of the width uncertain. This shape of characteristic was expected as a result of previous experience (18), and also from theoretical considerations of imagery in the electron optical system of the cathode ray tube.

In order to arrive at a method for determining the effective line width from the brightness distribution, consider the vertical definition of the picture. The worst condition that can arise is that the lines shall



ASSESSMENT OF EFFECTIVE LINE WIDTH FROM BRIGHTNESS DISTRIBUTION.

Fig. 15.

be alternately black and white, with the maximum range required. If the white line overflows its boundary the effect will be to reduce the brightness difference between it and the adjacent black lines. This is illustrated in Fig. 15 with reference to some of the characteristics given in the previous figures. It will be seen that the effective line width decreases with the contrast obtainable between it and the adjacent black line.

In view of the above, it is suggested that the line width of a television scanner (receiver or transmitter) might be defined as follows:—

The screen being scanned in a specified manner (e.g., as for the present B.B.C. transmissions), the line width shall be that within which an agreed proportion of the total flux falls, say, 98 per cent. In terms of the brightness distribution curves, this means that the area of the curve falling outside the limits on both sides shall be 1/50 of the area within. An alternative method would be to define the width in terms of the number of lines and screen height (e.g., 1/320 the picture height in the present case), and to give brightness characteristics for the line in terms of the light flux inside and outside the given boundary. Such curves are shown in Fig. 15.

If the effect of stray light on range is taken into account and the variation of picture brightness with spot diameter (or line width), then it will be seen that an increase in spot size, over that permissible according to the first of the two definitions proposed, will produce an overall increase in brightness, and therefore range, in the picture, but with resulting loss of range in the detail. The choice of line width for a given set of conditions is, therefore, subject also to the condition of producing the optimum effect in the picture. This has been confirmed by a simple experiment with a home cinema. The projector and screen were arranged so that the brightness of the projected picture, and the stray light falling directly on the screen, could be controlled within limits whilst the picture was being projected. By this means a very elementary control of both brightness and range were obtainable. Acceptable limits were then determined from the average opinion of a number of observers for sharply focussed and slightly defocussed pictures, and the results are given in Table IV. It will be seen that the lower quality definition is considered tolerable at fairly high range, 1.4-1.47 (25-30/1), and is considered comparable with the best focus at a lower range 1.17-1.3 (15-20/1). An overall brightness change of nearly 3/1 does not materially affect the judgment. This may be because the particular conditions used were not critical. The whole problem is at present under more detailed investigation as already stated. On no account should the above results be used as an argument for lower definition.

TABLE IV.

The effect of the inter-relation between range and definition, as shown by a home cinema picture.

Picture size 2′×1′6″. Brightnesses in e.f.c.

	White on Picture (W)	Black on Picture (without stray light on screen) (B)	Stray light on screen (without picture) (S)	Range $\log \frac{W}{B+S}$	Picture Quality
Projector correctly focused	2.5	0.05	0.04	1.45	Good
			0.10	1.23	Tolerable
			0.25	0.90	Bad
	7.0	0.14	0.04	1.59	Good
			0.10	1.46	Good
			0.25	1.25	Tolerable
Projector slightly out of focus (c. 240 line definition)	2.5	0.05	0.04	1.45	Tolerable
			0.10	1.23	Bad
			0.25	0.90	Intolerable
	7.0	0.14	0.04	1.59	Tolerable
			0.10	1.46	Tolerable
			0.25	1.25	Bad

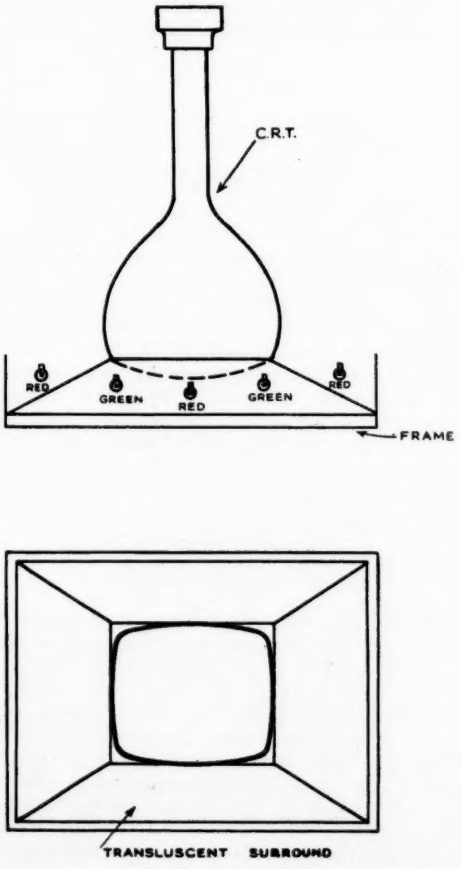
Present developments will, no doubt, be concentrated in the direction of greater light flux into the spot, and also to obtain a better distribution of light within it. The latter will both increase the brightness and reduce the "lininess" of the picture, without reducing the definition in any way.

With regard to the size of television pictures, it has already been shown (Fig. 4 and Table II.) that the viewing angle ϕ, is fixed from considerations of the definition of the picture, and hence if this value is adhered to, variations in picture size will be reflected in corresponding variations in viewing distance. The advantages of large pictures for the home would therefore seem to be negatived somewhat, due to the considerable viewing distance necessary. As and when definition is increased, then advantage can be taken of this to produce larger pictures. Larger pictures will also require greater light output from the receiver in order to maintain brightness. It has been suggested that larger cinema pictures do not require such high brightness (11), but this is unlikely to apply in the case of home television receivers, where, as has been shown, stray light on the screen is a limiting factor. The chief objection to the present size seems to be related to the comparative comfort with which a home cinema picture can be viewed by half a dozen people but the real difference here is in the relative definition.

(iii) Presentation and Tint.

The presentation of television images is at the moment the subject of much ingenuity. The relative merits of direct viewing versus mirror viewing (vertical cathode-ray tube) from the point of presentation versus cabinet dimensions, is much debated.

Direct magnifying lenses, giving magnification but restriction of the viewing angle, are also being tried with some success. The queston can be resolved into maintaining the contrast in the picture, and at the same time giving comfortable enjoyment of it. In this connection the use of an illuminated surround, particularly if of a contrasting tint to the picture itself (19), may be of considerable help. This possibility is being investigated in conjunction with the variable γ projectors already described (Fig. 9). A suitable arrangement for a cathode ray tube screen is shown in Fig. 16. Appreciable apparent changes in both colour and contrast can be brought about in this manner.



The coloured lamps are arranged alternatively red and green so that either colour or intermediate colours can be produced at will.

Fig. 16. Cathode Ray Tube Screen with Illuminated Coloured Surround Field.

With regard to presentation from the transmission end, it would seem reasonable to use lenses on the cameras giving the same values of ϕ as are normal at the receivers (Table II.).

The colour of the picture, in the case of cathode-ray tube receivers, is governed by the fluorescent compound used on the screen. This can now be made practically white with any suitable tint as desired. Mechanical mixtures of different powders are usually used, and the manufacturer then has under his control the exact tint of the resulting screen fluorescence. Here, then, a choice becomes available, sepia or cream, and blue/black being the tints generally favoured at the moment; these are generally related to soft and contrasty reproduction respectively as in the photographic case.

It is very desirable to be able to measure the colour of a cathode ray tube screen, both from the point of view of testing different combinations of powders and also for checking the reproducibility of the colour during the manufacture of the tubes. A photo-electric colorimeter, which has recently been developed (20), has proved very adaptable to this work.

This apparatus consists of three rectifier type photocells covered with suitable colour filters and connected respectively to three galvanometers. The spectral sensitivity curves of the three photocell filter combinations are arranged to approximate the tri-stimulus sensation curves of the I.C.I., XYZ tri-chromatic system. By a special optical system the galvanometers project line images, so arranged that, with the galvanometers at zero, these line images form an equilateral triangle. If the three photocell filter unit is held in front of the cathode ray tube so that the three cells are uniformly illuminated, the components from the three photocells cause deflections of the three galvanometers and movement of the three lines towards the centre of the triangle. By adjusting the total amount of light falling on the photocell, either by altering the distance from the tube, or, more simply, by varying the brightness of the scanning spot, the three lines can be made to intersect at one point. This point represents directly the location of the colour of the fluorescent screen of the cathode ray tube under test, within this particular tri-chromatic system, which approximates and is linearly related to the XYZ system. The measurements of a number of different fluorescent materials are given in Fig. 17, and for different

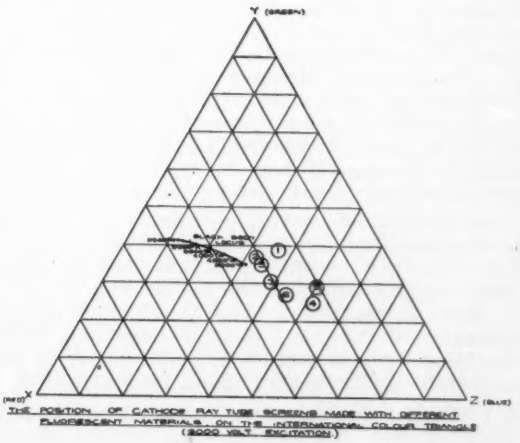

Y (GREEN)
X
Z (BLUE)
THE POSITION OF CATHODE RAY TUBE SCREENS MADE WITH DIFFERENT FLUORESCENT MATERIALS ON THE INTERNATIONAL COLOUR TRIANGLE (2000 VOLT EXCITATION)

Fig. 17.

voltages of excitation of one material in Fig. 18. The results are shown on the I.C.I. X Y Z trichromatic system of co-ordinates.

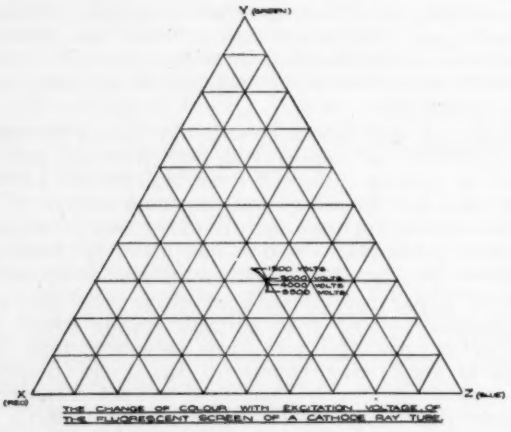


Fig. 18.

With regard to the actual brightness measurements of the colour-tinted screens, relative measurements for any one colour can readily be made with some degree of repetition accuracy by means of a selenium rectifier type of photocell, but accurate absolute values can probably only be obtained by initial visual calibration for each colour (21). Photocell readings should be regarded with suspicion unless such calibration is implied. Fortunately, the measurement of picture characteristics does not require very great accuracy, since logarithmic values are being dealt with and photoelectric, or portable photometers are quite suitable for this work. An absolute accuracy of 20 per cent. is then adequate.

(iv) Flicker.

With the type of scanning used in television it is not possible to interrupt the picture two or more times per frame as in the cinema, but an alternative method of overcoming flicker has been developed. (22). This consists of scanning all the odd lines of the picture first and then all the even ones. In this way the whole frame is covered twice for each picture giving, at twenty-five pictures per second, a fifty-cycle flicker, which is not noticeable. There is, however, an interline flicker which can be noticeable.

This method of scanning, known as interlaced scanning, requires very accurate adjustment of the whole television system to obtain perfect meshing of the two sets of lines. Very often this is not perfect, due to some defect or misadjustment in the transmitter or receiver, and the lines may tend to group themselves into pairs, or even appear to merge into each other if the spot size is too great (Fig. 19).

A preferred method of reducing flicker would be to maintain the intensity of each picture point for the duration of one complete picture by some light storage device, but this has not so far proved technically possible.

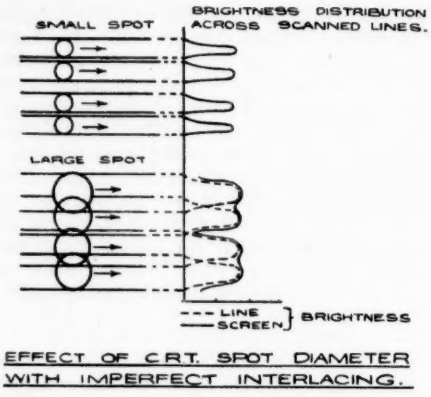


Fig. 19.

(5) Conclusion.

The present television system has so far proved capable of giving excellent home entertainment, provided programme material and methods of presentation suitable to the present standards are used. Receivers are capable of giving adequate brightness and range for home viewing, but precautions may have to be taken for daylight working, unless some considerable increase in brightness is forthcoming. Big changes in size are not likely to be welcomed until an increase in definition allows the adoption of larger pictures with the present viewing distance.

The best method of presentation of the picture is the subject of much experiment at the moment, and it is hoped that statistical evidence will be obtained with regard to this, and associated qualities such as contrast and colour, with the apparatus described above.

For the future remains large screen projection of high definition pictures, colour, and stereoscopic pictures. With regard to the former, it should be remembered that at least ten times the light flux is required to project a picture of the same size and brightness as that produced direct on the screen of a cathode ray tube, even using large aperture lenses. With regard to the two latter, especially colour, television is inherently so flexible a means of picture reproduction, that the perfection of higher definition will probably be all that is required to make it possible.

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DISCUSSION

Mr. T. M. C. LANCE said he was particularly interested in the experiments with the three photo-cells which had been shown for the purpose of measuring the colour of cathode ray tubes. Since television had become a popular form of entertainment, there had been a demand for standardisation of the colour of the screens. The public preferred a bluish white picture, and it was necessary for a manufacturer to hold his production with definite colour tolerances. From that point of view, therefore, he asked the authors for further information of the arrangement for testing with three photo-electric cells, and also the sort of variation in colour which would be obtained in practice around a given bluish white. Would it be possible, for example, to differentiate between the three cathode ray tubes exhibited by the authors, which showed slight variations in tint?

Mr. J. M. WALDRAM, congratulating the authors upon their work, said that the paper touched upon some things which were fundamental, not only in connection with television but with vision generally. The Society was to be congratulated upon having recently had three papers which dealt in part with these particular aspects. He was certain that development would be made in illuminating engineering through the study of the way in which we saw things. by experiments similar to the delightful method of varying the contrast which had been demonstrated. He felt that this was a type of study which ought to be pursued as thoroughly as possible. The authors would not claim to have found the optimum reproduction for cathode ray or any other form of picture presentation, but they had put us well on the way to finding it; and the methods which had been indicated would give very useful results. He felt that it was important to differentiate between a representation which was truthful and one which was pleasant—for it was possible to have a representation which was perfectly faithful but which yet would not make a good picture. It seemed likely that the problem of finding the most suitable picture characteristics for television involved this distinction.

The terms "visibility" and "contrast" were used by various writers in many different senses, and he had found himself a little confused in one or two places and by some of the figures, where the authors had used the word "contrast" where the more usual term was "range."

Mr. J. S. Dow referred to the possibility of television pictures being exhibited in a room furnished with moderate diffused illuminaton. Possibly experience of users in this matter would influence the public taste and thus lead to modification in the present practice of showing cinema films in complete darkness. As to the use of colour, the authors seemed to suggest that this was merely a matter of taste. Was it to be assumed that the colour of the light did not materially affect the definition of the picture or the degree of flicker? He would like to know whether there was any immediate possibility of televising pictures in colour. The difficulties at the moment seemed to be very formidable, but, perhaps, these might be overcome at a not too distant date.

Mr. G. H. WILSON, speaking on the practical problem of getting a pleasing television picture from the point of view of contrast and colour, quoted experience with the cinema. He understood from the cinema experts that they used a film or a positive print with a γ of about 1.2, i.e., the film as seen on the screen was very much more "contrasty" than the original, and he gathered from that that the cinema-going public liked to see a film with much contrast. Therefore, he imagined that the people who were going to "look in" to a television set would also want a picture probably of higher contrast than the original, as did the cinema people. Television tube designers would therefore have to bear in mind the popular opinion of the public in deciding on the contrast which they had in television pictures. By analogy with the cinema he very much doubted whether the authors' contention was correct, that as the public became more enlightened it would want a truer reproduction of the original scene, for that certainly had not been the case in the cinema.

On the question of colour there had very definitely

been a tendency in the cinema to go to bluer and bluer colours. The high intensity arc now universally used was very much bluer than the ordinary flame carbon arc, and he heard that in cinema theatres blue glass mirrors were being used with the arc in order to make the colour even more blue. Actually, these mirrors must absorb 20 or 30 per cent. more of the light than an ordinary mirror, and he believed many projectionists held the view that, although the picture on the screen was 20 to 30 per cent. darker, it looked brighter to the eye when such mirrors were being used. It seemed, therefore, that the popular opinion as to what looked a pleasing and brilliant picture might also be a controlling factor in the colour of the television tube.

It would be interesting to hear whether the authors had measured on their apparatus the colour of the high intensity arc, and whether they were trying to imitate that with some of their fluorescent powders.

With regard to the size of the picture seen in the cinema, he did not think one was getting the correct perspective from the more expensive seats in the cinema. These were usually at the back of the hall, and he would have expected the viewing distance for correct perspective to be not more than twice the picture width from the screen. Except when one was very close to the screen the distance of view did not appear to affect the realism very seriously, and this probably also applies to the television picture.

Mr. J. DENTON, speaking on behalf of the Television Society, expressed the thanks of that body for the kind invitation by the Illuminating Engineering Society to attend this meeting. At the same time, he extended a cordial invitation to the members of the Illuminating Engineering Society to attend any of the meetings of the Television Society at University College, which are held on the second Wednesday of the month, during the session, at 7 p.m.

Mr. F. P. BENTHAM suggested that too much stress had been laid on one aspect of television As this was the first meeting of the society to deal with the subject the treatment might well have been more general. No mention had been made of the field for the illuminating engineer in transmission, for instance.

The careful attention to the contrast value of the received picture had resulted in complete disregard of the most important factor in viewing, the "distraction factor." To him the fact that room lights or daylight reduced the contrast in the picture was of no consequence compared with the distraction that the light would reveal.

He had done a lot of televiewing in daylight, artificial light, and black out, and had come to the conclusion that it was quite impossible to concentrate on such a small picture unless the viewing room was in complete darkness. The casual methods of listening to radio (while talking or reading the paper) should not be perpetuated in televiewing. The development of the theatre had indicated that the auditorium should not be illuminated while the play is in progress. Why assume a different state of affairs for television? Therefore, they should not consider any other circumstances for viewing rooms than black out whatever the screen size. (Even a fire might distract.)

However, he was equally convinced that a neutral border illuminated with a low intensity was an advantage to television screen, and cinema screen alike. It would be quite impossible to appreciate paintings hung on jet black walls in an art gallery. This effect was even more noticeable in black and white, an etching without a white mount was inconceivable.

The proportions of such a border needed very careful design. He thought the light should be of low intensity and of the same tint as the standard of white in the received picture. Thus in cream and blue-white pictures, cream and blue-white borders were required respectively. This border would be of great importance when coloured television came in. A standard of white was essential to appreciate colour, but this, again, would not be a true white, but whatever tint that could be produced on the screen within the limits of the process. Incidentally, colour television on the low definition system was, he believed, demonstrated by Mr. Baird in 1928.

Lastly, he mentioned a possible field for lighting at the transmission end. Even the short period during which high definition television had been a public service was sufficient to show the difficulty of obtaining enough programme-hours of material in the future. There was no equivalent of music for television, seeing that a view of the orchestra had no attraction. In radio last year music accounted for over fifty per cent. of the total programme-hours. Therefore he would conclude with the prophecy that in the future (though not the immediate future), when screens were larger and colour an accomplished fact, light in the guise of "colour-music" would have a very large part to play. Perhaps television would provide the necessary impetus to the development of this art which had been so long deferred.

Mr. G. C. MARRIS, speaking of television from the point of view of a pleasing representation rather than a true representation, said he wondered whether consideration of that had gone far enough and whether this problem should not be looked at from the point of view of the romantic artist who was not concerned so much with pleasurable representation as with a striking representation. Perhaps the way to consider this problem was from the point of view of greater contrast than was the case at present. The ordinary things in life were very often judged not to be sufficiently contrasted, and for entertainment the tendency was to look to something that was a little more marked. There was not so much need to be careful about true representation except, perhaps, in the type of picture which was concerned with conveying information. Apart from that the aim should possibly be a pleasing picture of a striking character and from that point of view he liked the coloured surrounds which had been demonstrated. He would like to see experiments made to ascertain what the reaction would be to that device. With

regard to the lighting of cinemas whilst films were being exhibited, there was one theatre not far away in which the pictures, particularly colour films were spoiled by the fact that there were several definitely visible red lamps around both sides of the theatre.

Mr. L. S. HARLEY asked for the authors' ideas as to whether the most comfortable viewing distance with television was not rather greater than the linear dimension of the screen It seemed to him that the public which chose the most expensive seats in order to be some distance from the screen was doing the same thing, perhaps unconsciously, as an artist who stepped back properly to view his picture, and the distance might be put at something like four times the diagonal of the picture. That distance, applied to television, however, would take one too far from the picture for comfort.

Mr. R. G. HOPKINSON (communicated) said that he had understood the main purpose of the investigation was to discover the characteristics of the reproduction which the viewing public wanted, quite apart from whether this should be faithful or not. He knew from work he had done that there was a tendency on the part of most uncritical observers to choose a reproduction which gave a much brighter and more contrasty impression than did the original. He would, therefore, be very interested to follow the course of the investigation, and he hoped that it might be possible to divide observers into three classes, such as (a) experienced observers, (b) observers inexperienced in this particular work, but who could be described as critical observers, and (c) inexperienced observers. If this were done, it might be possible to interpret the results of the investigation in the most useful manner.

Whatever the result of the statistical determination, he hoped that it would be used for the producer's guidance only. He hoped that Mr. Winch and Mr. Jesty would agree that the ideal television receiver should give faithful reproduction, and that if any control of the tone rendering was considered necessary, this control should be made by the producer of the programme.

He believed that an illuminated surround to the picture had real value, not only in eliminating fatigue, but in helping to give more faithful reproduction. It was impossible to make any definite statement without having the necessary brightness readings; but in the cinema, certainly, the picture brightnesses were usually greater than he believed they should be for faithful reproduction. By the provision of a surround, the average brightness of the field of view was raised, and under these new viewing conditions the picture brightnesses were much more nearly correct for faithful reproduction.

Mr. L. C. JESTY, replying first to Mr. Lance, said that the colorimeter which had been demonstrated would discriminate very easily between variations of any one of the colours of the cathode ray tubes shown, and added that the information which Mr. Lance asked for with regard to the details of the device, would be published very shortly.

As to Mr. Waldram's remarks, he said the authors wished to make it quite clear that the apparatus which had been demonstrated for controlling brightness and contrast had only just been completed and it had not yet been possible to commence the investigations which were proposed. The authors felt that the television system should be faithful within prescribed limits and that the control of contrast should be made by the producer of programmes at the transmitter. It might be desirable to limit the range in the transmitting and receiving system. In the view of the authors, the correct procedure was to have a faithful reproduction and then to introduce such distortion as was desired, if it were possible, at the transmitter. He thanked Mr. Waldram for his criticisms of the use of the term "contrast" and proposed to correct this.

The point raised by Mr. Dow as to the surround brightness had already been dealt with in the American publication mentioned in the paper. The Americans had found, according to their published work, that the surround brightness was an optimum when it was of the order of 1-50th of the maximum brightness of the picture for the particular case they were dealing with. The authors believed that colour had an effect on flicker and on the appearance of the picture. One of the receivers on view that evening had the screen divided into two halves giving two colours, and the effect could be judged by those interested. It was hoped that full colour reproduction would eventually be possible, and, indeed, the authors believed it would become possible more quickly than in the case of the cinema, where a permanent record in colour had to be prepared. With direct television no such record was required, and the flexibility of the television system would be of great help in obtaining the correct adjustment of range and contrast for each colour.

Replying to Mr. Wilson on the question of faithful reproduction, he agreed that a γ greater than unity seemed to be the popular taste, or fashion, at the moment, but at the same time, care should be taken not to be too premature in accepting this statement as final. As to the angle of view, probably the discrepancy of opinions as to the desirable viewing distance might be due to the fact that the angle of view at a cinema was small in any case compared with that of a full plate photograph. Therefore, there would in all probability, be a much bigger range of viewing distance available for cinema pictures than there would be with a large photograph.

In reply to Mr. Bentham, the authors hoped to obtain some good advice for the programme producer and transmitting engineer from the results obtained with the variable γ projectors. With regard to the "distraction factor" of general illumination, it was the authors' experience, confirmed by the opinion of a number of other observers, that suitably directed diffuse lighting added to the comfort of viewing. When viewing in the daytime, of course, it is usually impossible to control the general illumination in the normal living room satisfactorily, unless high values of picture brightness are available at the receiver.

Commenting on the remarks by Mr. Marris in regard to the undesirability of faithful reproduction, Mr. Jesty said the authors still thought that such modification to the reproduction should be in the hands of the programme producer at the transmitter. A parallel might be drawn to the photographic case, where the development of panchromatic emulsions made photographic reproduction more faithful, and thus increased the scope of the photographer in the manner of lighting and make-up of his subject.

Referring to the viewing distance mentioned by Mr. Harley, it was remarked that to make a television set giving a viewing distance comparable with that of the cinema involved considerable increase in the perfection of the transmission and reception, and this standard had not yet been reached commercially.

As to general illumination in the room when television pictures were being viewed, Mr. Jesty said that the television set should be so placed with respect to the source of illumination as not to reduce the range of the picture. If this was not possible the picture brightness must be increased. The authors proposed a small amount of suitable general illumination, and also a surround field, because this had been found to give more comfortable viewing.

Mr. Hopkinson's suggestion that observers of picture quality should be classified into three groups would certainly be followed up with interest. The authors welcomed his plea that the control of picture quality should be only in the producer's hands. The B.B.C. and the receiver manufacturers should strive towards perfection of their reproducing system, with the object of providing the programme producer and his artists with a medium capable of reproducing their performance as exactly as possible on every receiver screen. The "viewer" should not be relied on to make adjustments to the receiver affecting picture quality, any more than a theatre audience was allowed to have any control in the stage lighting or make up of the actors; or a cinema audience allowed to choose the γ of the films projected.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."

RECOMMENDED VALUES OF ILLUMINATION

(First Revised Version).

August, 1937

The following "Recommended Values of Illumination," prepared by the Technical Committee of the Illuminating Engineering Society as an indication of Good Modern Lighting Practice, have been recently revised and extended. The Committee has also in view the preparation, as a supplement to this series of values, of some general explanatory statements regarding the principles of good lighting.

(a) This code gives **Recommended Illumination Values** on the working plane for various classes of work based upon good modern practice.

It is recognised that these recommendations will require revision from time to time in order to take cognisance of new investigations and changes in practice.

(b) **Service Values of Average Illumination.**

The values given are *Service Values of Average Illumination within* the area over which the visual task is carried out.

Where there is no definite area of work the illumination values are assumed to be available on a horizontal plane 2 ft. 9 in. from the floor.

The illuminating engineer must make allowances for depreciation. In practice the *Initial Values of Illumination should be higher than the service values it is desired to provide.*

(c) **Supplementary Local Lighting.**

The higher values may be obtained by supplementing the general lighting with local lighting, but the method of providing these illumination values is not specified, as this is a matter for the judgment of the illuminating engineer.

(d) **Uniformity of Illumination.**

These recommended values assume that there will not be undue variation in the values of illumination over the working area. In general it is considered that *no point of the working area shall be illuminated to less than 70 per cent. of the maximum.*

(e) **General Classification of Visual Tasks.**

Accompanying the code is a general classification of visual tasks together with the recommended illumination for adequate seeing conditions.

This classification forms the basis for the allocation of illumination values given in the table of specific tasks and in the case of visual tasks outside those enumerated provides a means of estimating the illumination required.

Present knowledge relating to seeing does not permit a precise statement of the illumination required for any visual task to be given, and the Committee has accordingly recommended ranges of illumination consistent with present good practice.

(f) **Colour Correction.**

Instances also arise in which the colour of the light as well as the provision of adequate illumination is an important condition.

VALUES OF ILLUMINATION RECOMMENDED AS ADEQUATE FOR VARIOUS TASKS.

	Recommended Foot-candle Value.	Class of Task.
1.	**Above 50**	Precision work to a high degree of accuracy; tasks requiring rapid discrimination; displays.
2.	**25—50**	Severe and prolonged visual tasks, such as fine engraving; discrimination or inspection of fine details of low contrast.
3.	**15—25**	Prolonged critical visual tasks, such as drawing, fine assembling, fine machine work, proof reading, sewing on dark goods, and type-setting.
4.	**8—15**	Visual tasks such as detailed office work, skilled bench-work, sustained reading and sewing on light goods.
5.	**5—10**	Less exacting visual tasks, such as in classrooms and general offices; casual reading and large assembly work.
6.	**3— 5**	Work of simple character not involving close attention to fine detail.
7.	**2— 4**	Casual observation where no specific work is performed.

RECOMMENDED ILLUMINATION VALUES

GENERAL.

	Foot-candles
Art Studios	**Special Lighting**
Cinemas	**Special Lighting**
Dance Halls	**Special Lighting**
Dentists' Surgeries	
Surgeries (chair)	**25—50**
Waiting rooms	**5—10**
Homes	
Bathrooms—	
General	**5—10**
Mirrors	**Special Lighting**
Bedrooms—	
Beds and mirrors	**Special Lighting**
General	**3—5**
Kitchens—	
Cookers, sinks, and tables	**5—10**
Nurseries	**5—10**
Reading—casual	**5—10**
Reading—sustained	**8—15**
Sewing	**15—25**
Students' homework	**8—15**
Table games	**5—10**
Workbenches	**8—15**
Hospitals	
Beds	**Special Lighting**
Corridors and stairways	**2—4**
Laboratories	**15—25**
Operating rooms	**15—25**
Operating tables*	**100—500**
Private rooms and wards	**2—4**
Receiving and waiting rooms	**5—10**
Hotels	
Bakeries	**5—10**
Bedrooms—	
Beds and mirrors	**Special Lighting**
General	**5—10**
Corridors and stairways	**2—4**
Dining rooms and lounges	**5—10**
Writing rooms—	
General	**5—10**
Tables	**Special Lighting**
Offices (including Banks)	
Book-keeping and typing rooms	**8—15**
Corridors and stairways	**2—4**
Drawing offices	**25—50**
General offices and private offices	**5—10**
Public Buildings	
Churches:—	
Church halls	**5—10**
Church interiors	**3—5**
Libraries:—	
Backs of books	**2—4**
Book rooms	**5—10**
Corridors and stairways	**2—4**
Reading rooms	**5—10**
Museums:—	
Corridors and stairways	**2—4**
General interiors	**5—10**
Showcases	**Special Lighting**
Public Halls:—	
Corridors and stairways	**2—4**
General interiors	**5—10**
Schools	
Art and drawing rooms	**15—25**
Classrooms, libraries, and offices	**5—10**
Corridors and stairways	**2—4**
Dressing rooms, toilet, and wash rooms	**5—10**
Gymnasiums	**5—10**
Laboratories	**8—15**
Lecture theatres	**5—10**
Manual training rooms	**8—15**
Sewing rooms	**15—25**
Shops (including Restaurants and Stores)	
Automobile showrooms	**8—15**
Bakeries	**5—10**
Corridors and stairways	**2—4**
Dressing rooms, toilet and wash rooms	**5—10**
Large departmental stores	**15—25**
Refreshment rooms	**5—10**
Restaurants	**5—10**
Shops	**8—15**
Sports (including Indoor Recreations)	
Badminton, indoor cricket, indoor tennis, racquets, and squash	**Special Lighting**
Billiards—	
General	**2—4**
Tables	**15—25**
Bowling, on alleys and runways	**8—15**
Gymnasiums	**5—10**
Skating rinks	**5—10**
Theatres	**Special Lighting**

INDUSTRIAL

	Foot-candles
Assembly Shops	
Extra fine work	**25—50**
Fine work	**15—25**
Medium work	**8—15**
Rough work	**5—10**
Book-Binding	
Assembling, cutting, embossing, folding, pasting, punching, and stitching	**8—15**
Burnishing and Polishing	**8—15**
Cements and Clay	
Cleaning and lumming, colouring and glazing, enamelling, moulding and pressing,	**8—15**
Filter pressing, grinding and kiln rooms	**5—10**
Cloth Cutting, Inspecting, and Sewing	
Dark goods	**15—25**
Light goods	**8—15**
Coal Breaking	
Control point and picking belts	**15—25**
Screening and washing	**2—4**
Die Making	**25—50**
Drawing Offices	**25—50**
Engraving	**above 50**
Flour Milling	
Baking, cleaning, grinding, roasting, and rolling	**5—10**
Foundries	
Charging the cupola, cleaning, pouring, shaking out, and tumbling	**5—10**
Fine core making and fine moulding	**8—15**
Rough core making and rough moulding	**5—10**
Garages	
General	**5—10**
Repair department	**8—15**

* Installations where artificial daylight may be useful.

RECOMMENDED ILLUMINATION VALUES

	Foot-candles
Glass Works	
Bevelling, decorations, etching, fine grinding, and inspection	15—25
Cutting glass to size, glass-blowing machines, grinding, pressing, and silvering	5—10
Fine inspection and glass cutting (cut glass)	25—50
Furnace rooms and mixing	3—5
Glove Manufacturing	
Cutting, inspecting,* knitting, pressing, sorting,* stitching, and trimming	15—25
Hat Manufacturing	
Brading, cleaning, dyeing, finishing, flanging, forming, ironing, refining, and stiffening	8—15
Sewing	15—25
Inspection (Colour of light according to requirements)	
Extra Fine	25—50
Fine	15—25
Medium	8—15
Rough	5—10
Jewellery and Watchmaking	25—50
Leather Manufacturing	
Cleaning, stretching, and tanning	3—5
Cutting, fleshing, and stuffing	5—10
Finishing and scarfing	8—15
Vats	2—4
Leather Working	
Cutting, grading, matching, scarfing, and sewing*	15—25
Pressing and winding	8—15
Machine Shops	
Extra fine bench and machine work	25—50
Fine automatic machines, fine bench and machine work, fine buffing and polishing, and medium grinding	15—25
Medium bench and machine work, medium buffing and polishing, ordinary automatic machines and rough grinding	8—15
Rough bench and machine work	5—10
Paint Shops*	5—10
Paper Box Manufacturing	
Manufacturing	5—10
Storage of stock	3—5
Paper Manufacturing	
Beaters and grinding	5—10
Calendering	8—15
Cutting, finishing, and trimming	15—25
Plating	5—10
Power Houses	
Auxiliary equipment, battery rooms, blowers, boilers, coal and ash handling, compressors, engines, generators, oil switches and transformers, switchboards	5—10
Gauges	**Special lighting**
Printing Industry	
Casting, matrixing, miscellaneous machines and presses	8—15
Colour printing*	15—25
Electro-typing, lithographing and proof reading	15—25
Imposing, linotype, monotype, stone engraving, and type-setting	25—50
Packing and sorting	5—10
Rubber Manufacturing	
Bead building, calenders, compounding, inner tube operation, mechanical goods, mills fabric preparation, pneumatic tyre building and finishing, solid tyre operations, stock cutting, treading, tubing machines, trimming and vulcanising	5—10
Sheet Metal Works	
Fine bench work, miscellaneous machines, ordinary bench work, presses, punches, shears, stamps, and welders	8—15
Tinplate inspection	15—25
Shoe Manufacturing	
Cutting, hand turning, lasting and welting, miscellaneous bench and machine work	8—15
Inspecting and sorting	15—25
Stitching	25—50
Smiths' Shops	
Fine forging and welding	5—10
Rough forging	3—5
Soap Manufacturing	
Cutting, kettle houses, soap chip and powder	3—5
Filling and packing soap powder, stamping, wrapping, and packing	5—10
Steel and Iron Mills (Bar, plate, and wire)	
Automatic machines, rod, light and cold rolling, shearing fine by line, wire drawing	8—15
Casting and charging floors	5—10
Cleaning, heavy rolling, pickling, shearing rough by gauge	3—5
Plate inspection	5—10
Reheating furnaces and soaking pits	2—4
Stores	
Heavy	2—4
Light	5—10
Structural Steel Works	5—10
Sugar Grading	15—25
Sweet Making*	8—15
Testing	
Extra fine instruments, scales, etc.	25—50
Fine	8—15
Rough	5—10
Tobacco	
Drying	2—4
Grading and sorting*	15—25
Stripping	5—10
Upholstering	
Automobile, coach and furniture	8—15
Warehouses	2—4
Welding	8—15
Woodworking	
Cooperage, glueing, medium machine and bench work, planing, rough sanding, sizing, and veneering	8—15
Fine bench and machine working, fine sanding and finishing	15—25

* Installations where artificial daylight may be useful.

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